Retrieval of Particulate Matter from MERIS Observations

Wolfgang von Hoyningen-Huene,
Alexander Kokhanovsky,
John P. Burrows
University of Bremen, Institute of Environmental Physics
Otto-Hahn-Allee 1, D-28334 Bremen, Germany
hoyning@iup.physik.uni-bremen.de

The determination of particulate matter (PM) from space-borne aerosol observations in terms of spectral aerosol optical thickness is required to fill in gaps between ground-based stations of the national air quality networks and to get information on PM for regions with no or poor access to ground-based network data. It is a relevant information for environmental control.

Since satellites give normally columnar observation of the whole atmosphere, and PM data are valid only for the atmospheric boundary layer, the satellite-derived data for columnar PM must be reprocessed to account for conditions at the ground (e.g., at 2m height as observed by ground stations). Therefore the retrieval of PM requires the integration of very different information: (a) aerosol optical thickness (AOT), (b) aerosol type and composition, (c) vertical profile and distribution of aerosol and (d) humidity.

The present contribution integrates spectral AOT retrievals using MERIS L1 data made with the Bremen AErosol Retrieval (BAER) approach, von Hoyningen-Huene et al. (2003), with the estimation of effective radius, number concentration and finally mass load within an atmospheric column. Assessmets of density, planetary boundary layer (PBL) height and average relative humidity yield the transfer of these information into concentrations of PM10.

Method of PM Retrieval

The retrieval of particulate matter from satellite observation uses spectral properties of AOT, as derived by BAER for clear sky conditions. The retrieval of AOT provides for 7 short-wave channels of the MERIS instrument the spectral behaviour of AOT, which is used for the determination of the spectral slope in terms of the Angström α-parameter. Angström α is obtained using AOT, retrieved from the 7 MERIS channels with wavelength ≤ 0.665 µm.The BAER approach is described by von Hoyningen-Huene et al (2003, 2004) and is used in different applications, Kokhanovsky et al. (2004), Lee et al. (2004, 2005). AOT for a certain reference wavelength, here MERIS channel 1 or 2 with 0.412 or 0.443 µm is used, and the Angström α-parameter are the basis for the PM retrieval followed.

The PM retrieval self requires an assessment of a size distribution model to convert spectral AOT into columnar aerosol volume, respectively mass. Kokhanovsky et al. (2006) use a mono-modal logarithmic size distribution, characterized by the effective radius r_{eff} and a fixed mode width σ = 0.8326. Mie theory is used to derive parameterisations for r_{eff} and extinction factor as a function of spectral slope of AOT $\delta_{Aer}(\lambda)$, expressed by the Angström α-parameter: $r_{eff} = f_1(\alpha)$, $q_{ext} = f_2(\alpha)$. Both quantities give together with the AOT a columnar number concentration of aerosol:

$$n_{Aer} = 8 \cdot \delta_{Aer}(0.412\mu m) \frac{1}{\pi \cdot r_{eff}^2 \cdot q_{ext}} \quad . \qquad (1)$$

Thus a dynamical link between the spectral AOT and columnar number concentrations is obtained. The selected mono-modal size distribution fits to the size range, relevant for PM10.

An assessment of aerosol density ρ_{Aer} relates the columnar number concentration to an estimate of the columnar aerosol mass in the atmospheric column and considering meteorological conditions to PM10:

$$PM10 \approx \frac{a}{h_{PBL}} \frac{\pi}{6} \rho \cdot n_{Aer} r_{eff}^3 \cdot f(RH) \, . \qquad (2)$$

For the estimation of PM concentrations the columnar aerosol mass needs to be related to the planetary boundary layer (PBL) conditions. Under clear sky conditions about 90 % of aerosol are within the PBL and the PM10 concentration has to be related to the dry state. Therefore a correction for humidity effects will be required., where f(RH) is given by Hänel (1984). The parameter *a* gives the fraction of total aerosol, which is within the PBL and the h_{PLB} characterizes the thickness of PBL. The approach is described in detail by Kokhanovsky et al. (2006) together with an application.

PM10 retrieval over Germany

For the purpose of PM10 retrieval the MERIS L1 scene with reduced resolution (1.2 x 1.2 km²) of October 13. 2005, 09:45:11 UTC over central Europe is selected. It shows the most parts of Germany as cloud free. Spectral AOT and Angström α-parameter has been retrieved, using BAER approach. Using the approach above, effective radius, columnar aerosol number concentration and finally PM10 has been derived from satellite observations, Fig. 1. Since effective radius is very sensitive to disturbances in Angström α, a rigorous screening for sub-pixel cloud effects is required. The ratio of standard deviation to average of a gliding 5 x 5 pixel mask is used as a criterion for homogeneity of PM10 results.

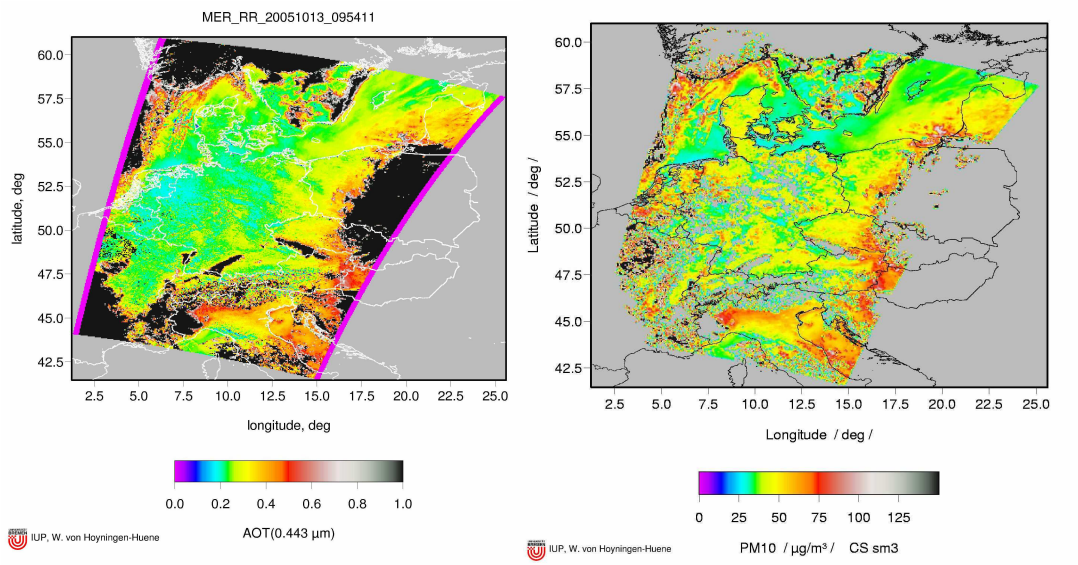

Fig. 1: left: AOT for MERIS channel 2 (0.443 µm) from scene of October 13, 2005 over central Europe. right: PM10 concentrations, estimated from the same scene.

The PM10 estimates over Germany are in magnitude and tendency comparable with ground-based measurements of Umweltbundesamt (Federal Environmental Agency of Germany).

References

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